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August 11, 2010

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Mr. Bradley Arnold
County Administrator
Sumter County
910 North Main Street
Bushnell, FL 33513

Mr. Brad McNeill
Project Manager
C W Roberts Contracting, Inc.
4208 CR 124-A
Wildwood, FL 34785

RE: FIN: 428095-1-58-01 & 428096-1-58-01
FAP: ARRA 574-B & ARRA 575-B
Contract: APT44 & APT46
Sumter County - **C 470 From Lake Panasoffkee Outfall Canal to SR 44 and CR 476E From US 301 to SR 471**
Change Order No. 2- Warm Mix Asphalt

Dear Mr. Arnold and Mr. McNeill,

C W Roberts Contracting, Inc. (CWR) has submitted a request to use a Warm Mix Asphalt on these projects in lieu of the Hot Mix Asphalt which was originally proposed. Their request is to use the Warm Mix for a portion of the shoulder asphalt (12.5) and for Friction Course (FC-9.5) called for in the contract.

The FDOT issued Materials Bulletin No. 03-09 and DCE Memorandum No. 03-09 to address and permit the use of this mix. The Bulletin and Memorandum are attached along with supporting documentation from CWR. By allowing the use of this mix, the Specifications in the FDOT Bulletin and Memorandum are incorporated into the contract for these projects.

It is Volkert's recommendation that the Warm Mix be approved as a no cost Change Order to these contracts. If you are in agreement with this Change Order please sign indicating your concurrence below.

C W Roberts, Inc. should sign the concurrence and transmit the package to Sumter County for their signature. There are three originals. After completion please return the Change Orders to Volkert for distribution

Sincerely,

Thomas Thursby
Project Administrator, Volkert Construction Services

Concur by Brad McNeill, C W Roberts, Inc. 8-13-10
Date

Concur by Bradley Arnold Sumter County 8-17-10
Date

Attachments

SUMTER CR 470 & 476

# Florida Department of Transportation

CHARLIE CRIST
GOVERNOR

5007 Northeast 39th Avenue
Gainesville, Florida 32609

STEPHANIE KOPELOUSOS
SECRETARY

March 26, 2009

**MATERIALS BULLETIN NO. 03-09**
**DCE MEMORANDUM NO. 03-09**
***(FHWA Approved: 3/25/09)***

**TO:** DISTRICT MATERIALS RESEARCH ENGINEERS
DISTRICT CONSTRUCTION ENGINEERS

**FROM:** Thomas O. Malerk, P.E., Director, Office of Materials
David A. Sadler, P.E., Director, Office of Construction

**COPIES:** Bob Burleson, Jim Warren, Jim Musselman, Chris Richter (FHWA)

**SUBJECT:** WARM MIX ASPHALT

The use of warm mix asphalt will be addressed in a future revision of the Standard Specifications. In the interim, this memorandum is issued to provide specification language for warm mix asphalt for projects where the Contractor has proposed to use warm mix asphalt and the Engineer has agreed to its use.

Replace subarticle 330-3.2.2 with the following:

**330-3.2.2 Temperature:** Spread the mixture only when the air temperature in the shade and away from artificial heat is at least 40°F for layers greater than 1 inch (100 lb/yd2) in thickness and at least 45°F for layers 1 inch (100 lb/yd2) or less in thickness (this includes leveling courses). The minimum temperature requirement for leveling courses with a spread rate of 50 lb/yd2 or less is 50°F. The minimum ambient temperature requirement may be reduced by 5°F when using warm mix technology, if mutually agreed to by both the Engineer and the Contractor.

Replace subarticle 334-3.2.1 with the following:

**334-3.2.1 General:** Design the asphalt mixture in accordance with AASHTO R35 04, except as noted herein. Prior to the production of any asphalt mixture, submit the proposed mix design with supporting test data indicating compliance with all mix design criteria to the Engineer. For Traffic Level B through E mix designs, include representative samples of all component materials, including asphalt binder. Allow the State Materials Engineer a maximum of four weeks to either conditionally verify or reject the mix as designed.

For Traffic Level C through E mix designs, final verification of the mix design will occur when the requirements of 334-5.1.2.1 have been met. Do not use more than three mix designs per nominal maximum aggregate size per traffic level per binder grade per contract year. Exceeding this limitation will result in a maximum Composite Pay Factor of 1.00 as defined in 334-8.2 for all designs used beyond this limit.

Warm mix technologies (additives, foaming techniques, etc.) listed on the Department's website may be used in the production of the mix. The URL for obtaining this information, if available, is:
http://www.dot.state.fl.us/statematerialsoffice/quality/programs/warmmixasphalt/index.shtm

The Engineer will consider any marked variations from original test data for a mix design or any evidence of inadequate field performance of a mix design as sufficient evidence that the properties of the mix design have changed, and the Engineer will no longer allow the use of the mix design.

Replace subarticle 334-3.2.7 with the following:

**334-3.2.7 Additional Information:** In addition to the requirements listed above, provide the following information with each proposed mix design submitted for verification:

1. The design traffic level and the design number of gyrations (Ndesign).
2. The source and description of the materials to be used.
3. The DOT source number and the DOT product code of the aggregate components furnished from a DOT approved source.
4. The gradation and proportions of the raw materials as intended to be combined in the paving mixture. The gradation of the component materials shall be representative of the material at the time of use. Compensate for any change in aggregate gradation caused by handling and processing as necessary.
5. A single percentage of the combined mineral aggregate passing each specified sieve. Degradation of the aggregate due to processing (particularly material passing the No. 200 sieve) should be accounted for and identified.
6. The bulk specific gravity (Gsb) value for each individual aggregate and RAP component, as identified in the Department's aggregate control program.
7. A single percentage of asphalt binder by weight of total mix intended to be incorporated in the completed mixture, shown to the nearest 0.1 percent.
8. A target temperature for the mixture at the plant (mixing temperature) and a target temperature for the mixture at the roadway (compaction temperature) in accordance with 330-6.3. Do not exceed a target temperature of 330°F for modified asphalts (PG 76-22, ARB-5, and ARB-12) and 315°F for unmodified asphalts.
9. Provide the physical properties achieved at four different asphalt binder contents. One of which shall be at the optimum asphalt content, and must conform to all specified physical requirements.
10. The name of the CTQP Qualified Mix Designer.
11. The ignition oven calibration factor.
12. The warm mix technology, if used.

Replace subarticle 337-2.1 with the following:

**337-2.1 General Requirements:** Meet the requirements specified in Division III as modified herein. The Engineer will base continuing approval of material sources on field performance. Warm mix technologies (additives, foaming techniques, etc.) listed on the Department's website may be used in the production of the mix. The URL for obtaining this information, if available, is: http://www.dot.state.fl.us/statematerialsoffice/quality/programs/warmmixasphalt/index.shtm

Replace subarticle 337-7.3 with the following:

**337-7.3 Temperature Requirements for FC-5:**

**337-7.3.1 Air Temperature at Laydown:** Spread the mixture only when the air temperature (the temperature in the shade away from artificial heat) is at or above 65°F. As an exception, place the mixture at temperatures no lower than 60°F, only when approved by the Engineer based on the Contractor's demonstrated ability to achieve a satisfactory surface texture and appearance of the finished surface. The minimum ambient temperature may be further reduced to 55°F when using warm mix technology, if agreed to by both the Engineer and the Contractor.

**337-7.3.2 Temperature of the Mix:** Heat and combine the asphalt rubber binder and aggregate in a manner to produce a mix having a temperature, when discharged from the plant, meeting the requirements of 330-6.3. Meet all requirements of 330-9.1.2 at the roadway. The target mixing temperature shall be established at 320°F. The target mixing temperature may be reduced when using warm mix technology, if agreed to by the Engineer and the Contractor.

Replace subarticle 337-7.5.1 with the following:

**337-7.5.1 Air Temperature at Laydown:** Spread the mixture only when the air temperature (the temperature in the shade away from artificial heat) is at or above 45°F. The minimum ambient temperature may be reduced by 5°F when using warm mix technology, if agreed to by both the Engineer and the Contractor.

This memorandum serves as a blanket approval to process a no-cost specification change for on-going projects and should be attached to the Work Order or Supplemental Agreement accomplishing this task.

For any questions concerning this matter, please contact Greg Sholar, (352) 955-2920, or Pat Upshaw, (352) 955-2906, at the State Materials Office.

TM/DS/smw

# *STATE OF FLORIDA*

# FDOT's Experience with Warm Mix Asphalt

Research Report
FL/DOT/SMO/09-527

Gregory A. Sholar
Tanya M. Nash
James A. Musselman
Patrick B. Upshaw

October 30, 2009

## STATE MATERIALS OFFICE

## INTRODUCTION

Warm mix asphalt (WMA) is asphalt mix produced at a lower temperature than conventional hot mix asphalt (HMA). Temperature reductions are typically in the range of 40-75°F less than HMA. The ability to produce and place asphalt mix at a reduced temperature is accomplished through the addition of an additive (either water or a chemical) to the asphalt binder prior to mixing with the aggregate or into the asphalt drum during the mixing process.

The benefits of using WMA are: 1) reduced burner fuel consumption at the asphalt plant, 2) lower emissions (smoke and fumes) from the asphalt mix, 3) better workability of the mix resulting in better compactability and easier handwork, 4) ability to pave in cooler weather due to a slower mix cooling rate in the workable temperature range of the WMA, and 5) less aging of the asphalt binder during production.

Concerns with the use of WMA are: 1) incomplete drying of the aggregate (especially with absorptive limestones), 2) potential for increased moisture susceptibility when utilizing WMA processes that use water, 3) unknown effects of chemical additives on the long term performance of the asphalt binder, 4) concerns with the WMA's ability to provide enough radiant energy to heat the reclaimed asphalt component in mixtures containing reclaimed asphalt pavement (RAP), and 5) lack of overall long term performance information.

The Florida Department of Transportation, herein referred to as the Department, started using WMA on a trial basis in 2006, with a slow, gradual increase in usage to date. Table 1 shows the number of warm mix projects constructed by the Department per year.

**Table 1 – Number of Warm Mix Projects Constructed per Year**

| Year | Number of Projects Constructed |
|---|---|
| 2006 | 1 |
| 2007 | 2 |
| 2008 | 2 |
| 2009 (as of October 2009) | 11 |

In March 2009, Materials Bulletin/Construction Memorandum 03-09 was issued by the Department providing specification language for the use of WMA for projects where the Contractor proposed its use, at no additional cost, provided the Engineer's approval was obtained. Subsequent to the bulletin, the Department's standard specifications were modified to allow the use of warm mix asphalt for all asphalt mixture types, at the Contractor's option, effective with the January 2010 letting.

This report will focus on the following areas: 1) a detailed analysis of the first three warm mix projects constructed by the Department, 2) an overview of all of the projects constructed to date, and 3) an analysis of the differences in construction variability between HMA and WMA.

## DETAILED ANALYSIS OF THE FIRST THREE WMA PROJECTS

The first three WMA asphalt projects (one in 2006 and two in 2007) were constructed by different Contractors and utilized different warm mix technologies. This section will provide a detailed discussion of each project, including laboratory performance test data, construction test data and pavement condition survey information.

**SR-417, Seminole County, FIN 413669-1-52-01, Turnpike District**

This project consists of a 0.758 mile test section of FC-5 open graded friction course placed in the southbound passing lane of SR-417 (see Figure 1) utilizing the Aspha-min WMA process. Directly to the north of the WMA test section is a 1.024 mile control section, consisting of the same FC-5, without the Aspha-min additive. Both mixtures contain a polymer modified PG 76-22 asphalt binder and were constructed in February 2006.

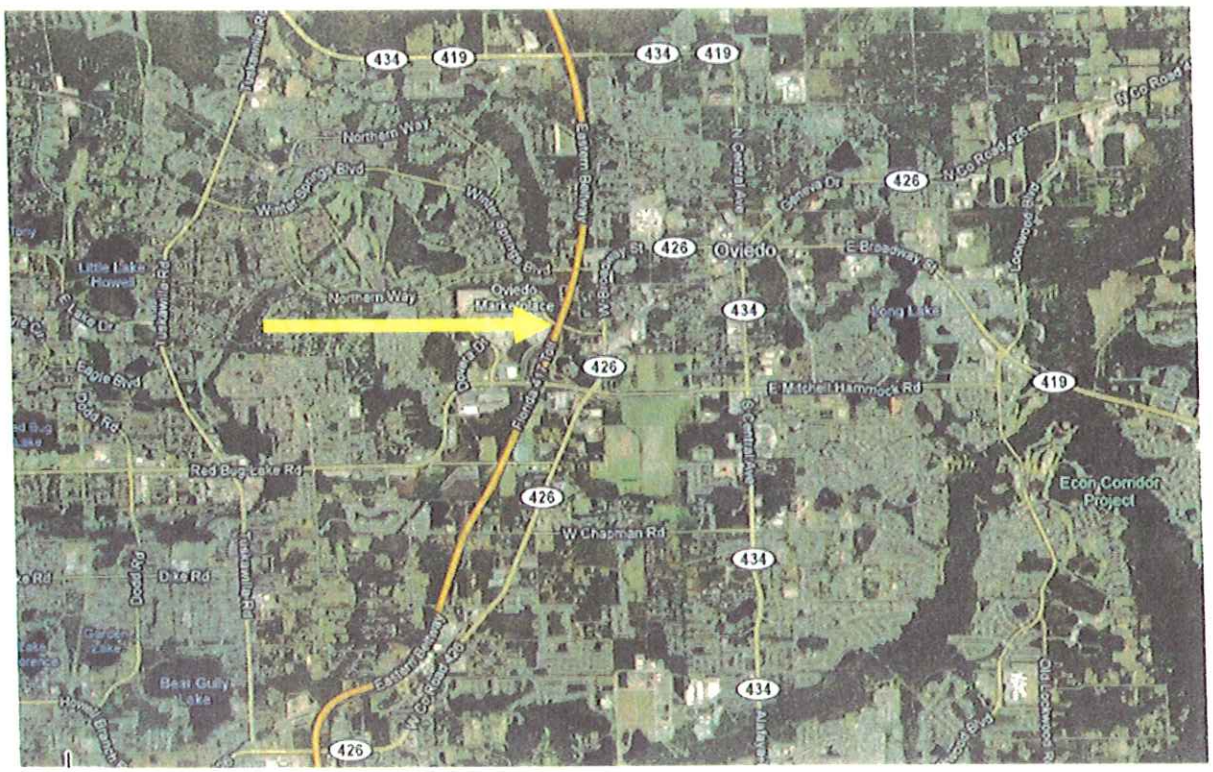


**Figure 1 - SR-417 Project Location**

Aspha-min is a white powder (Zeolite) that is injected into the asphalt drum at a rate of 6 lb. per ton of asphalt mixture (see Figure 2). This is equivalent to 0.3% by weight of asphalt mixture.

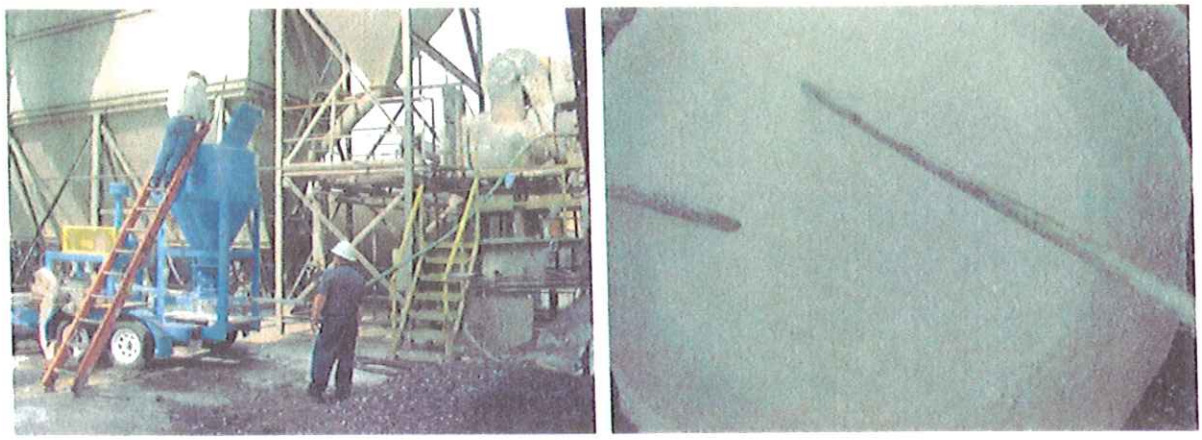

**Figure 2 - Aspha-min Warm Mix Process**

The mixing temperature for the HMA control mixture was 320°F and the mixing temperature for the WMA mixture was 270°F. During construction, the temperatures of the asphalt mat measured directly behind the paver were in the range of 280-290°F for the HMA mixture and 250-260°F for the WMA. State Material Office staff observed no issues with the placement of either mixture.

Samples of each mixture type were obtained and tested for their cracking properties utilizing the Energy Ratio concept developed at the University of Florida. A higher Energy Ratio indicates better resistance to cracking. The Energy Ratio results are presented in Table 2 and the results show that the WMA mixture had slightly better cracking properties than the HMA mixture.

**Table 2 – Energy Ratio Test Results for SR-417 Project**

| Performance Measurement | Mixture Type | |
|---|---|---|
| | HMA FC-5 | WMA FC-5 |
| Energy Ratio | 0.47 | 0.60 |

Pavement condition surveys (PCS) were performed in May 2006 and July 2009, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 3 and show that there are no practical differences between the HMA and WMA sections.

**Table 3 – PCS Test Results for SR-417 Project**

| Performance Measurement | PCS Test Date and Mixture Type | | | |
|---|---|---|---|---|
| | May 2006 | | July 2009 | |
| | HMA FC-5 | WMA FC-5 | HMA FC-5 | WMA FC-5 |
| Rutting (inches) | 0.00 | 0.00 | 0.00 | 0.00 |
| Crack Rating (max = 10.0) | 10.0 | 10.0 | 10.0 | 10.0 |
| Ride Number (max = 5.0) | 4.10 | 4.05 | 4.13 | 4.04 |

**US-92 (SR-600), Polk County, FIN 197259-2-52-01, District 1**

This project consists of a 1.164 mile test section of SP-12.5 structural mix placed in the eastbound travel and passing lanes of US-92 in Lakeland (see Figure 3) utilizing the Evotherm DAT WMA process. Directly to the west of the WMA test section is a 0.634 mile control section, consisting of the same SP-12.5 mixture, without the Evotherm additive. Both mixtures contain a polymer modified PG 76-22 asphalt binder and were constructed in October 2007. Subsequently, a conventional HMA FC-5 open graded friction course mixture was placed over the structural mix.

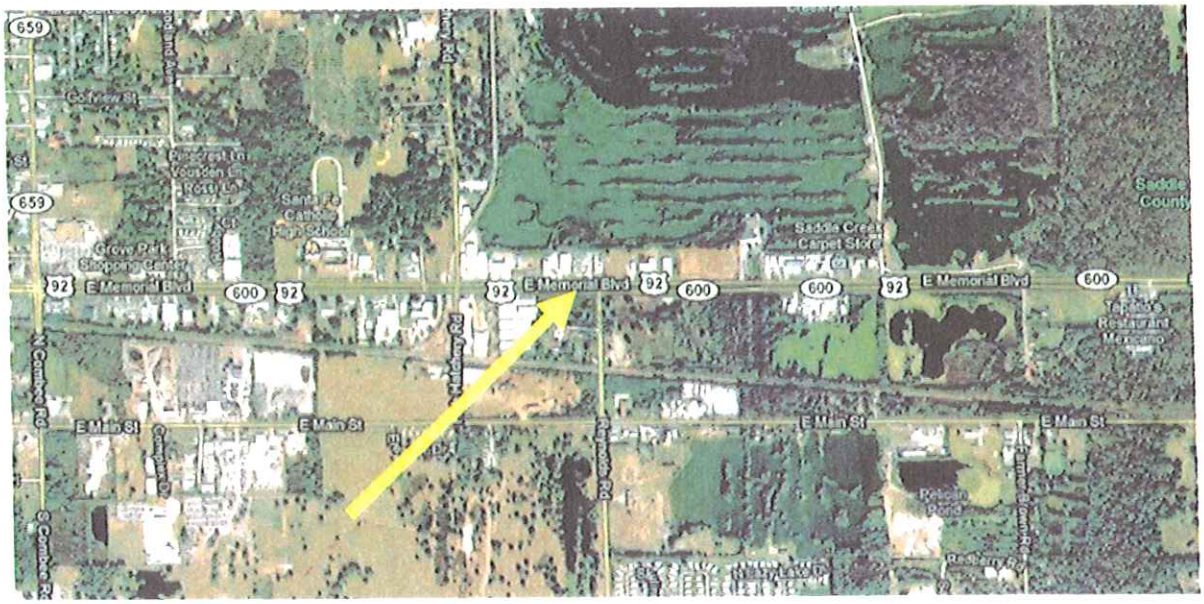


**Figure 3 - US-92 Project Location**

Evotherm DAT is a chemical additive that is injected into the asphalt binder supply line at a rate of 5% by weight of binder (see Figure 4).


**Figure 4 - Evotherm DAT Warm Mix Process**

The mixing temperature for the HMA control mixture was 325°F and the mixing temperature for the WMA mixture was 250°F. During construction, the temperature of the asphalt mat measured directly behind the paver was approximately 230°F for the WMA. There were no issues with placement of the WMA mixture.

Samples of each mixture type were tested for their cracking properties utilizing the Energy Ratio concept, their rutting performance utilizing the Asphalt Pavement Analyzer (APA), and their resistance to moisture damage utilizing the retained tensile strength approach per test method FM 1-T 283. The performance test results are presented in Table 4 and the results show that the WMA and HMA mixtures performed the same with the exception of moisture resistance, in which the HMA mixture had slightly better test results than the WMA mixture.

**Table 4 – Laboratory Performance Test Results for US-92 Project**

| Performance Measurement | | Mixture Type | |
|---|---|---|---|
| | | HMA SP-12.5 | WMA SP-12.5 |
| Energy Ratio | | 1.66 | 1.64 |
| APA Rut Depth (mm) | | 2.8 | 2.8 |
| Moisture Damage Testing | Dry Strength (psi) | 204.3 | 206.3 |
| | Conditioned Strength (psi) | 142.8 | 133.7 |
| | Tensile Strength Ratio (%) | 70 | 65 |

Pavement condition surveys were performed in November 2007 and December 2008, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 5 and show that there are no practical differences between the HMA and WMA sections.

**Table 5 – PCS Test Results for US-92 Project**

| Performance Measurement | PCS Test Date and Mixture Type (Results are from Traffic Lane) | | | |
|---|---|---|---|---|
| | November 2007 | | December 2008 | |
| | HMA SP-12.5 | WMA SP-12.5 | HMA SP-12.5 | WMA SP-12.5 |
| Rutting (inches) | 0.03 | 0.03 | 0.04 | 0.05 |
| Crack Rating (max = 10.0) | 10.0 | 10.0 | 10.0 | 10.0 |
| Ride Number (max = 5.0) | 4.06 | 4.02 | 4.07 | 4.11 |

**SR-11, Flagler County, FIN 417141-1-52-01, District 5**

This project consists of a 9.6 mile test section of SP-12.5 structural mix placed in the southbound and northbound lanes of SR-11, south of Bunnell (see Figure 5), utilizing the Astec Double Barrel Green WMA process. Directly to the north of the WMA test section, in the northbound lane, is a 4.9 mile control section, consisting of the same SP-12.5 mixture, without utilizing the Astec WMA process. Both mixtures contain a RA-800 asphalt binder and 45% fractionated RAP. The test sections were constructed in December 2007 and January 2008. Subsequently, a conventional HMA FC-12.5 dense graded friction course mixture was placed over the structural mixtures.

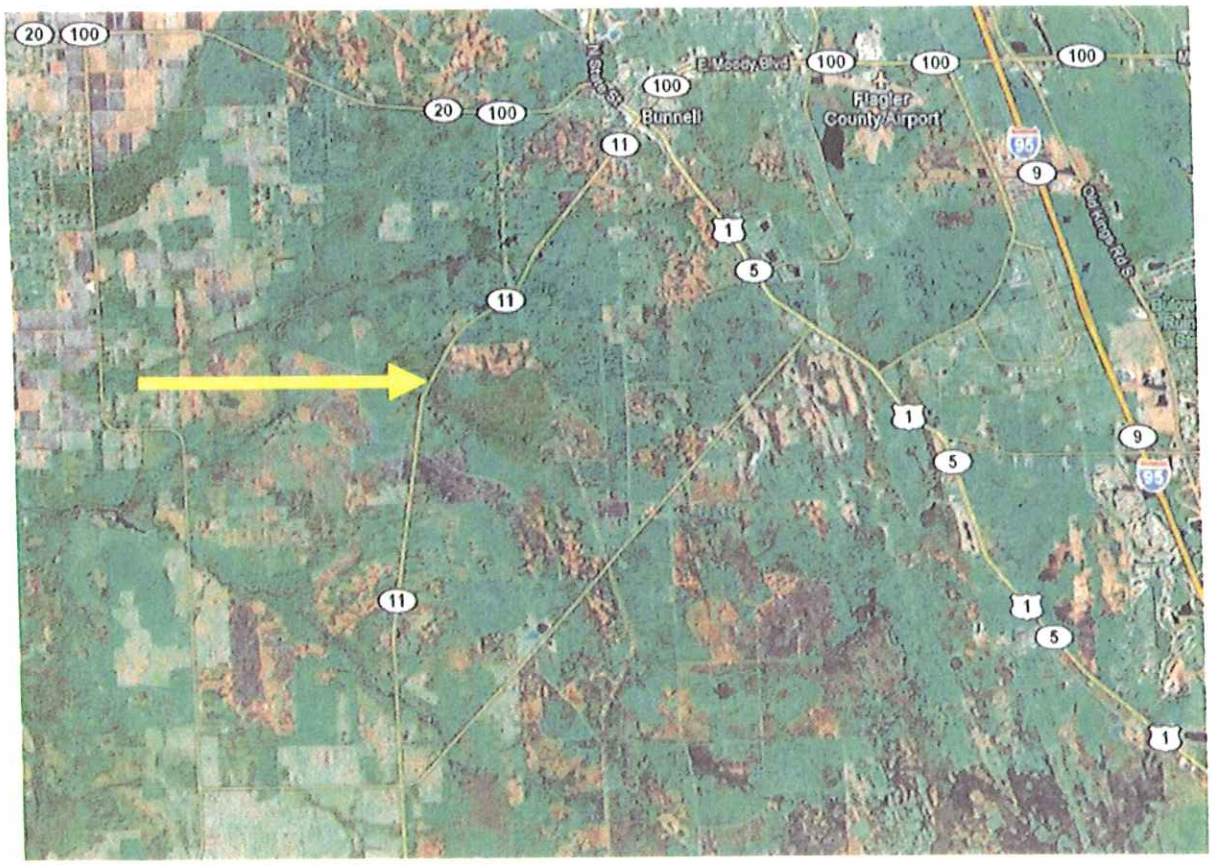


**Figure 5 - SR-11 Project Location**

The Astec Double Barrel Green WMA process is a foaming process that injects water into the asphalt binder supply line at a rate of 2% by weight of binder (see Figure 6). Astec claims that a large proportion of the water vaporizes instantly, leaving approximately 0.5% water by weight of binder to provide the enhanced mixture workability.

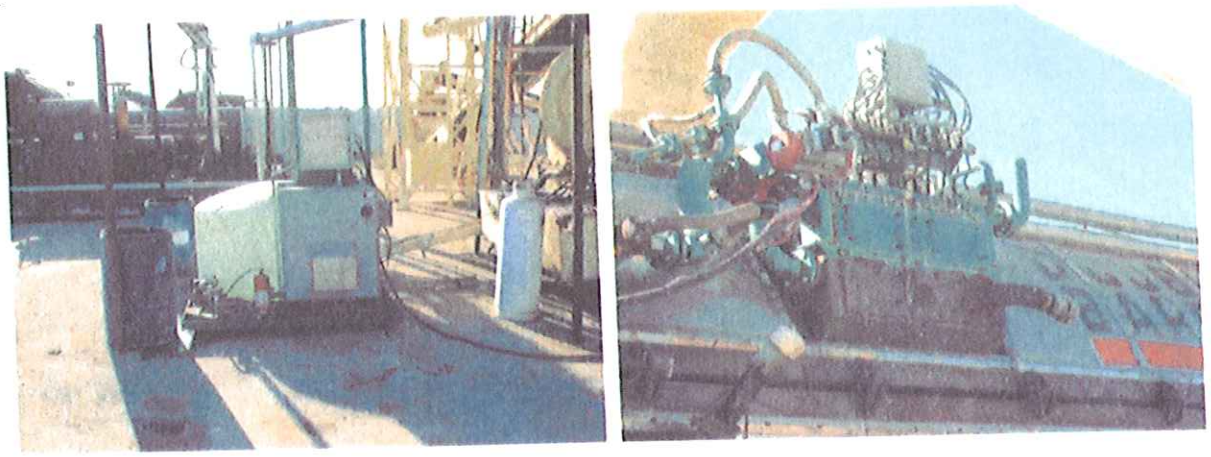

**Figure 6 - Astec Double Barrel Green Warm Mix Process**

The mixing temperature for the HMA control mixture was 310°F and the mixing temperature for the WMA mixture was 270°F. During construction, the temperature readings of the warm mix measured in the haul trucks varied substantially (from 250 to 290°F) due to the Contractor producing several mixture types for several projects within the same day. However, no issues with placement of the WMA mixture were noted.

Samples of each mixture type were tested for their cracking properties utilizing the Energy Ratio concept, their rutting performance utilizing the Asphalt Pavement Analyzer (APA), and their resistance to moisture damage utilizing the retained tensile strength approach per test method FM 1-T 283. The performance test results are presented in Table 6 and the results show that the WMA mixture performed slightly better than the HMA mixture with respect to cracking and rutting and nearly as well with respect to moisture damage resistance.

**Table 6 – Laboratory Performance Test Results for SR-11 Project**

| Performance Measurement | | Mixture Type | |
|---|---|---|---|
| | | HMA SP-12.5 | WMA SP-12.5 |
| Energy Ratio | | 1.70 | 1.85 |
| APA Rut Depth (mm) | | 4.1 | 2.7 |
| Moisture Damage Testing | Dry Strength (psi) | 211.5 | 198.2 |
| | Conditioned Strength (psi) | 129.0 | 115.1 |
| | Tensile Strength Ratio (%) | 61 | 58 |

Pavement condition surveys were performed in June 2008 and July 2009, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 7 and show that there are no practical differences between the HMA and WMA sections.

**Table 7 – PCS Test Results for SR-11 Project**

| Performance Measurement | PCS Test Date and Mixture Type (Results are from Traffic Lane) | | | |
|---|---|---|---|---|
| | June 2008 | | July 2009 | |
| | HMA SP-12.5 | WMA SP-12.5 | HMA SP-12.5 | WMA SP-12.5 |
| Rutting (inches) | 0.03 | 0.05 | 0.04 | 0.06 |
| Crack Rating (max = 10.0) | 10.0 | 10.0 | 10.0 | 10.0 |
| Ride Number (max = 5.0) | 4.32 | 4.36 | 4.29 | 4.34 |

## SUMMARY OF ALL WARM MIX PROJECTS CONSTRUCTED TO DATE

The previous section of this report presented detailed laboratory performance test data and pavement condition survey data for the first three WMA projects constructed, which utilized three different WMA technologies, encompassing the major types of WMA processes used in Florida to date. Table 8 provides a summary of every WMA project constructed by the

Department, as of October 2009. To date, nearly 226,000 tons of WMA have been placed in six of the eight Districts in the state, utilizing five different WMA technologies. Note that three of the five WMA technologies (Astec Double Barrel Green, Meeker, and Terex) are all foaming processes that inject water into the asphalt binder supply stream. There have been no construction or performance problems noted on any of the WMA projects.

**Table 8 – Summary of All WMA Projects Constructed as of October 2009**

| District | Project Number | Route | County | Mix Type | Quantity (tons) | Additive Technology | Construction Date | Contractor | Mixing Temperature | Compaction Temperature | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 195259-2 | US-92 | Polk | SP-12.5 | 2383 | Evotherm | 10-2007 | Lane Construction | 280 | 230 | Mainline |
| | 195353-2 | US-92 | Polk | SP-9.5 | 4900 | Evotherm | Current | Lane Construction | 280 | 230 | Mainline |
| | | | | SP-9.5 | 2680 | | | | 280 | 240 | Mainline |
| | | | | FC-9.5 | 2680 | | | | 280 | 240 | Mainline |
| | 197767-1 | I-27 | Polk | FC-5 | 6579 | Astec DBG | 04-2009 | Orlando Paving | 260 | 260 | Mainline |
| 1 | 197383-3 | SR-700 | Sarasota | SP-9.5 | 3020 | Meeker | Current | Ajax | 265 | 265 | Mainline |
| | | | | SP-12.5 | 4080 | Terex | | | 270 | 270 | |
| | | | | SP-9.5 | 8890 | | | | 270 | 270 | |
| | | | | FC-12.5 | 1174 | | | | 290 | 290 | |
| | 196938-1 | US-301 | Manatee | SP-12.5 | 5680 | Meeker | Current | Ajax | 290 | 290 | Mainline |
| | | | | FC-5 | 3344 | | | Ajax | 290 | 290 | Mainline |
| | 199055-1 | I-75 | Collier | SP-12.5 | 473 | Meeker | Current | Ajax | 275 | 275 | Shoulders |
| | | | | SP-12.5 | 4885 | | | | 275 | 275 | |
| | | | | SP-12.5 | 26405 | | | | 265 | 265 | |
| | | | | FC-5 | 7159 | | | | 290 | 285 | Mainline |
| 2 | 209233-1 | SR-262 | Duval | SP-12.5 | 9725 | Astec DBG | Current | Duval Asphalt | 265 | 265 | Shoulders |
| 3 | 415257-1 | I-10 | Gadsen | SP-12.5 | 4080 | Astec DBG | Current | C.W. Roberts | 270 | 260 | Shoulders |
| | 415358-1 | I-10 | Jefferson | SP-12.5 | 8907 | Astec DBG | 02-2008 | Anderson Columbia | 260 | 250 | Shoulders |
| | | | | SP-12.5 | 1511 | | 04-2008 | | 260 | 250 | |
| | 416069-1 | I-10 | Walton | SP-12.5 | 1125 | Astec DBG | 08-2008 | Anderson Columbia | 260 | 250 | Shoulders |
| | | | | SP-12.5 | 3650 | | 08-2008 | | 260 | 250 | |
| 5 | 417141-1 | SR-11 | Flagler | SP-12.5 | 2900 | Astec DBG | 12-2007 | PAVE Paving | 270 | 260 | Mainline |
| | | | | SP-12.5 | 3973 | | | | 270 | 260 | Mainline |
| | 419841-1 | SR-25 | Lake | FC-5 | 36259 | Astec DBG | 03-2009 | Orlando Paving | 250 | 250 | Mainline |
| | | | | SP-12.5 | 51898 | | | | 265 | 265 | Mainline |
| 7 | 257026-1 | US-19 | Pinellas | SP-12.5 | 537 | Astec DBG | Current | APAC Southeast | 260 | 260 | Mainline |
| | | | | SP-12.5 | 8089 | | | | 260 | 260 | Mainline |
| | 416639-1 | US-98 | Pasco | FC-12.5 | 8089 | Astec DBG | Current | APAC Southeast | 260 | 260 | Mainline |
| 8 | 413669-1 | SR-41 | Seminole | FC-5 | 2730 | Asphamin | 02-2009 | Orlando Paving | 270 | 270 | Mainline |
| Total Tonnage 225,889 | | | | | | | | | | | |

## ANALYSIS OF CONSTRUCTION VARIABILITY

To ascertain the difference in construction variability between WMA and HMA, an analysis of construction test data was conducted between WMA mixtures and HMA mixtures that were placed on the same project. Similar mixtures, within the same layer, were analyzed. A total of 11 projects and 12 mixture types were examined (three FC-5 mixtures, eight SP-12.5 mixtures, and one FC-12.5 mixture). A summary of the projects and mixture types is provided in Table 9.

**Table 9 – Summary of WMA and HMA Projects Used for Analysis of Construction Variability**

| Project Number | Mixture Type | Warm Mix Process |
|---|---|---|
| 1 | FC-5 Open Graded | Aspha-min |
| 2 | SP-12.5 Dense Graded | Evotherm DAT |
| 3 | SP-12.5, FC-12.5 Dense Graded | Astec DBG |
| 4 | SP-12.5 Dense Graded | Astec DBG |
| 5 | SP-12.5 Dense Graded | Astec DBG |
| 6 | SP-12.5 Dense Graded | Astec DBG |
| 7 | SP-12.5 Dense Graded | Astec DBG |
| 8 | SP-12.5 Dense Graded | Meeker |
| 9 | FC-5 Open Graded | Astec DBG |
| 10 | SP-12.5 Dense Graded | Astec DBG |
| 11 | FC-5 Open Graded | Astec DBG |

The standard deviation of the test results for gradation and asphalt binder content are graphically presented for both WMA and HMA FC-5 open graded friction course mixtures in Figure 7. The standard deviation of the test results for gradation, asphalt binder content, air voids, and roadway density are graphically presented for both WMA and HMA dense graded mixtures in Figure 8. The horizontal bars in Figures 7 and 8 represent the average standard deviation for each type of production (WMA and HMA).

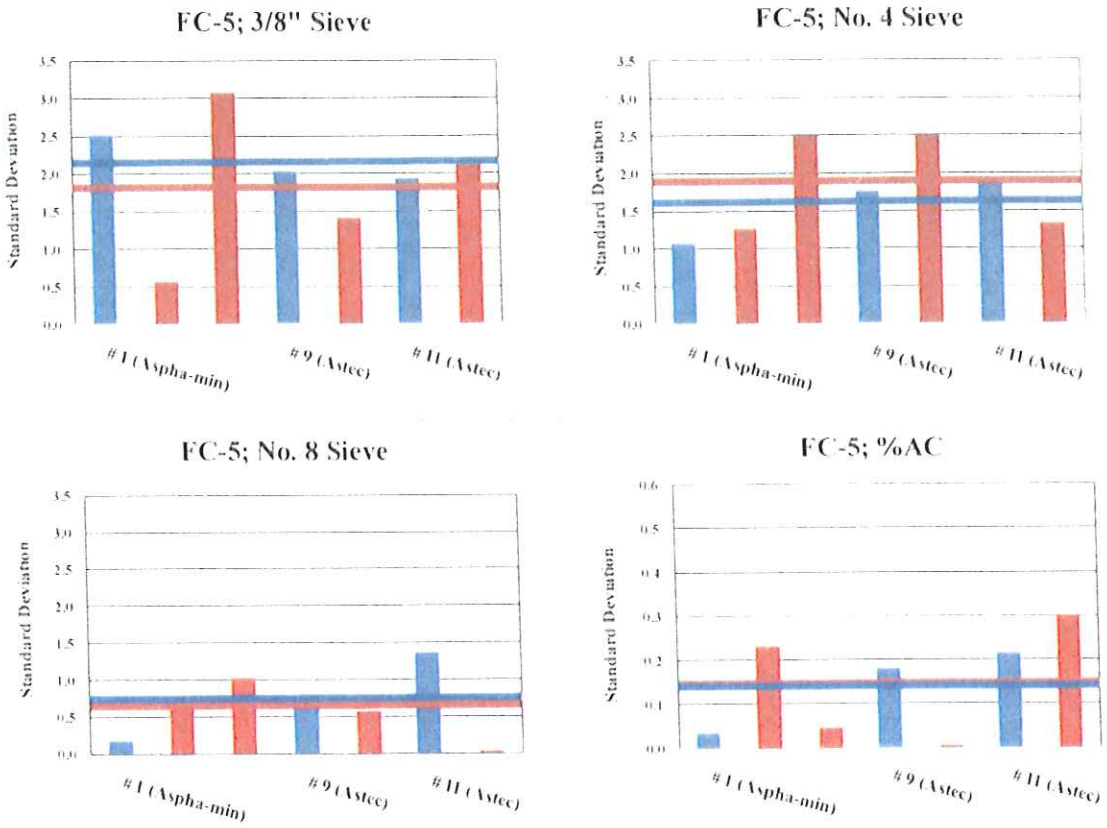


Figure 7 - Construction Variability for FC-5 Open Graded Friction Course Mixtures (Blue = Warm Mix Asphalt; Red = Hot Mix Asphalt)

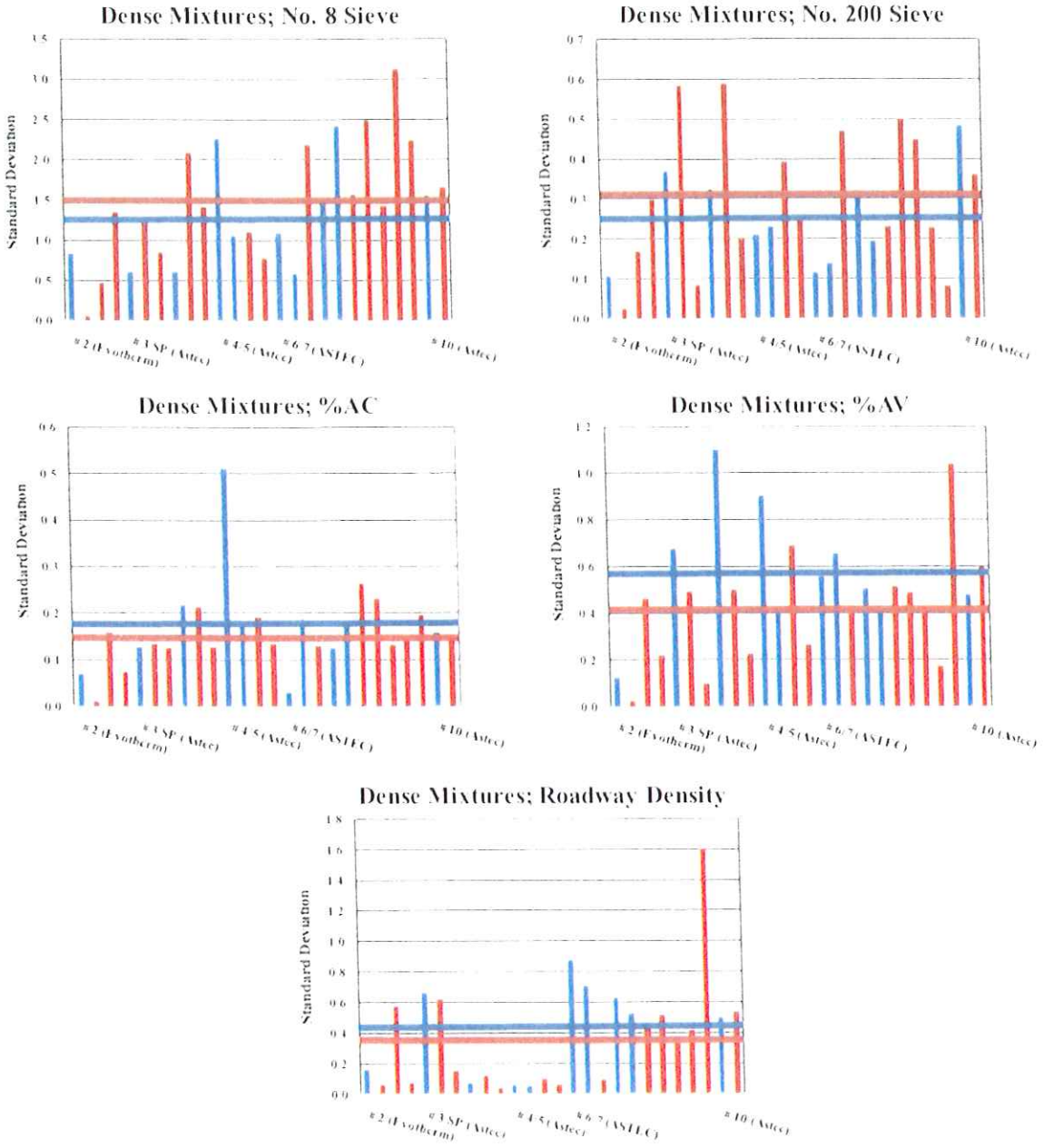


**Figure 8 - Construction Variability for Dense Graded Friction Course Mixtures (Blue = Warm Mix Asphalt; Red = Hot Mix Asphalt)**

As can be seen in Figures 7 and 8, the construction variability is similar between WMA and HMA, with some properties/projects having lower variability with WMA and some having higher variability.

## CONCLUSIONS

This report has provided a summary of the Department's experience with WMA to date. A detailed analysis of the first three projects was provided indicating that there is no significant difference in laboratory performance or in measured pavement condition survey data (rutting, cracking and ride evaluation) between the WMA and HMA sections of the same mixture. Additionally, a listing of all of the WMA projects constructed to date was presented showing that nearly 226,000 tons of WMA has been placed in structural mixtures, dense graded friction course mixtures, and open graded friction course mixtures, utilizing five different WMA processes. To date, there have been no construction or performance problems noted on any of the projects. An analysis of construction variability indicated that there is no significant difference in the variability of measured quality control properties (binder content, air voids, gradation and roadway density) between companion WMA and HMA mixtures in the same project.